# Appendix C

# GIS Data Report

Geographic Information Services and Consulting
assisting with geographic information systems analysis and support for:
Programmatic Environmental Impact Statement for
DNRC State Trust Land Special Uses Division

**Prepared for DNRC State Trust Land Special Uses Division**

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# Introduction

This report details the geographic information system analysis and support for strategic planning associated with State Trust Lands. The GIS services involved data procurement, processing, analysis, and graphic support for DNRC staff and contracted researchers working on economic and social assessments of state trust lands. Geodata Services, Inc. developed GIS layers combining commercial and residential property with state trust land parcels and ancillary geospatial data in order to provide a foundation for assessing the relative potential of state trust lands to allow commercial, industrial, residential or other special uses. GIS analysis was also used by Dr Jackson in the financial analysis using a nearest neighbor approach, combining Montana Department of Revenue land appraisal values, with land use codes, residential housing density, development rates by decade, proximity measures to commercial and industrial properties. Individual properties were combined into aggregate summaries by county for acreage classifications of residential, commercial and industrial properties.

This appendix report is divided into the following sections:

1. Data sources and summary description
2. Methods and analysis procedures
3. GIS deliverables
4. Analysis results

# Data Sources and Summary Description

## *Data sources*

Geographic Information Systems (GIS) was used in this project to calculate geospatial variables for subsequent analysis and modeling of commercial and residential potential of state trust lands. Base layers include the following layers and sources and their accompanying summary description and synopsis of their use.

**Montana cadastral ownership maps maintained by the Department of Administration.**

This layer provided the base for all private residential land and commercial properties in Montana. It included coverage in every county, though some counties were still incomplete. The Information Services Division of the Montana Department of Administration provided Geodata with a statewide geodatabase of the parcel layer based on the July, 2003 status of the ownership parcels. The databases for this system are updated twice each year. This geodatabase with approximately 800,000 parcels was used for two portions of the analysis, measuring distances to residential, commercial and industrial properties from each DNRC trust land parcel, and calculating housing density, year built, within the neighboring areas around each trust land parcel.

The parcels included a geocode, which is an identification number intended to be unique for each parcel. The Department of Revenue Computer Assisted Mass Appraisal System (CAMA) included the residential and commercial property tax system. A centroid point was derived for each parcel and these points were overlaid on the land office polygons and each parcel assigned to a land office. The parcels and centroid points were linked to the residential CAMA database via the geocode identifier. A similar process was used to link the parcels to the commercial CAMA database for commercial and industrial parcels.

***Digital Elevation Model***
A statewide digital elevation model (DEM), with a 30 meter resolution was obtained from the Natural Resource Information System at the Montana State Library. To facilitate subsequent processing, the DEM was resampled to a resolution of 90 meters. A slope map, calculated in percent, was created from the resampled DEM. The slope map was also reclassified to identify slopes greater than 25% which were too steep for septic systems, forming a portion of the identification of developable areas. It was also used as a modifier in the floodplain surrogate buffer. The DEM was also used to derive a shaded relief grid, used as a backdrop for presentations and map graphics.

***State Trust Land Parcels***
The state trust land GIS layer used for this analysis was provided by DNRC GIS staff. Neither DNRC staff, nor Department of Revenue or Department of Administration staff had integrated state CAMA geocodes into the state trust land database or digital GIS file. In spite of these limitations, this GIS data layer was used as it was without additional modification as the base state trust land layer for this project, and without trying to match the parcels spatially to the cadastral GIS layer to match geocodes. The GCDB survey control that the state trust lands layer was based on was also updated. As a result of these considerations there were small anomalies and geographic slivers resulting from the overlays that we were forced to accept in the course of analysis. Overall, they had minimal impact on the outcome. Each DNRC trust land parcel was also used as the source for Thiessen polygon neighborhood delineation, which were the neighborhood polygons used in this analysis for variables measured at the neighborhood level.

***Roads***
Broad coverage of roads was available at a scale of 1:100,000 based on Census based Tiger files. The public domain files were available from the Montana state library. This project used the ESRI nationwide street database in ArcGIS StreetMap USA from Geographic Data Technology, Inc. (GDT) commercially enhanced street files, built on this Tiger base but enhanced with more recent development and more roads. This street database enhances TIGER 2000 source data and provides a nationwide base map for routing and drive time analysis. Although many small rural roads and forest roads are not on these layers, they include most paved county roads and generally represent the development potential for most areas. Roads were used in the

proximity analysis for potential development, and in the economic valuation nearest neighborhood analysis. The GDT roads layer is a proprietary commercial GIS layer.

***Business Locations***

ESRI Business Analyst software includes a national database of more than 12 million U.S. businesses from InfoUSA, which was used to supplement the Montana cadastral data and provide an alternative measure of commercial site proximity. These data include sites not available through the Montana commercial CAMA data. The CAMA data was based on property ownership, the InfoUSA was based on business address. Between these two commercial geospatial map layers, most commercial activity in Montana were mapped at a level of detail suitable for nearest neighbor analysis at a fine grained scale. The ESRI Business Analyst data also included shopping center data. The National Research Bureau tracked the following information on nearly 14,000 shopping centers with more than 100,000 square feet of gross leasable area (GLA) across the United States: alphabetical listing, center name, metropolitan statistical area (MSA), city, county, market positioning strategy, space availability, planned/proposed/new centers, expanding/renovating centers, major owner, leasing agent, and management. These were provided by point location based on address, and used in the proximity analysis. This database did not contain any shopping centers in the Eastern Land Office. They were also used to extract hospital locations, a key variables in the residential growth analysis. The InfoUSA and NRB GIS layers are a proprietary commercial GIS layers.

***Airports***

This data set includes airports in the United States, Puerto Rico and the U.S. Virgin Islands. The data were derived from an extract of the Public Use Airports database of the National Transportation Atlas Databases-2001 (NTAD-2001), published by the Bureau of Transportation Statistics, Department of Transportation. This map layer included airports in the 50 United States, Puerto Rico, and the U.S. Virgin Islands with enplanements greater than or equal to 250 passengers per year. There were 21 airports in the database in Montana, and all were used in the analysis.

***Streams***

The National Hydrography Dataset (NHD) is a comprehensive set of digital spatial data that contains information about surface water features such as lakes, ponds, streams, rivers, springs and wells. Within the NHD, surface water features are combined to form "reaches," which provide the framework for linking water-related data to the NHD surface water drainage network. These linkages enable the analysis and display of these water-related data in upstream and downstream order. The NHD is based upon the content of USGS Digital Line Graph (DLG) hydrography data integrated with reach-related information from the EPA Reach File Version 3 (RF3). The NHD supersedes DLG and RF3 by incorporating them, not by replacing them. Users of DLG or RF3 will find the National Hydrography Dataset both familiar and greatly expanded and refined. It was initially developed at a scale of 1:100,000. This stream layer was used for distance measurements.

***Demographic Data***

ESRI Business Analyst software contains over 300 demographic variables. This study used the household change between 1990 and 2000 and the predicted change between 2003 and 2008 as part of the analysis for potential residential growth and for the financial nearest neighbor analysis. The geographic units for this analysis was census block groups. The ESRI Business Analyst layer is a proprietary commercial GIS layer.

***Public Land Ownership***

The NRIS program at the Montana State Library maintains a 1:100,000 scale public land ownership and stewardship layer. This layer was used for distance measures to public lands and to extract state trust land areas under some form of conservation easement. This layer was not regularly maintained, it was not up to date everywhere in the state, and it did not include county and municipal lands. However, it was the best composite layer for public lands and was used as is with no further checks or modifications. The Montana Cadastral map layer and CAMA included public land ownership, but tended to lump all federal and state lands into single categories, so the parcel layer was not used in this study to identify public lands used in subsequent proximity analysis.

***Floodplain***

Another portion of the developable land base identification was based on floodplain areas, which were less likely to be developed. Digital versions of floodplain maps, developed and maintained by the Federal Emergency Management Agency were available for portions of 17 Montana counties, representing a small percentage of the total area. To simulate floodplains consistently throughout Montana a one-quarter mile buffer zones around all perennial streams (based on the National Hydrologic Data at a scale of 1:100,000)was weighted inversely by slope to create a variable width estimated floodplain that was narrower where slopes were steep.

***Miscellaneous Layers***

For general mapping and location reference, county, state, river, lakes, towns and cities were required. This project used layers provided by NRIS, typically at the 1:100,000 scale or smaller.

***DNRC field offices and regions***

Field office boundaries were acquired from DNRC GIS staff in digital form and used as is with no further modifications.

## GIS Deliverables

The primary deliverable product for this contract was a GIS layer of state trust land parcels with accompanying database containing the attributes measured in this study and metadata and documentation on the map layers and analysis process. The DNRC land office boundaries layer is also included as a deliverable. This layer was provided by

DNRC and no changes were made to it. The following attributes were developed and included in the state trust land parcel database:

Distance and proximity

<u>Distance measurements from state trust land parcels to variables related to residential growth</u>

- Residential parcels with existing residences in the Montana cadastral property database (All residences /5 yr/10 yr)
- Commercial parcels in the Montana cadastral property database
- Industrial parcels in the Montana cadastral property database
- Commercial businesses in the InfoUSA database
- Shopping centers in the NRB shopping centers database
- Conservation easements
- Perennial streams
- Public land
- Roads
- Hospitals
- Airports with emplanements greater than or equal to 250 passengers per year

<u>Acreage summaries of selected characteristics for each state trust land parcel</u>

- Floodplain
- Slopes greater than 25%
- Developable area (slopes < 25% and not floodplain)
- Road access
- Contiguity to other state trust land parcels forming blocks of land larger than 1 square mile in size.
- Standard deviation of elevation
- Road density

<u>Acreage summaries of selected characteristics for the neighborhoods surrounding each state trust land parcel</u> (Thiessen polygons were used to define neighborhoods and are defined as the area that is closest to the parcel centroid relative to all other parcel centroids)

- Average value of the year residence built, year remodeled, effective year modifier, land value attributes, count of residences in neighborhhood, housing density per acre were derived to aid Dr Jackson to fit a regression model. Land value attributes and the count of commercial and industrial parcels were also derived.
- Change in the number of households from 1990 to 2000 and the predicted annual change from 2003 to 2008

<u>Summarization of quantiles</u>

The values for the distance measurement variables and the neighborhood values were categorized into quantiles by each land office and assigned a high, medium, or low class value (High=>75%, Medium=50-75%, Low=<25%)

Residential Model Calculation

The residential model was calculated by summing the quantile values for the following attributes. Quantiles were calculated by each land office.

- Distance to the nearest residence
- Distance to the nearest residence built in the last five years
- Distance to the nearest perennial stream
- Distance to the nearest state or county road
- Distance to the nearest commercial business (by address)
- Distance to the nearest major shopping center
- Distance to the nearest commercial parcel
- Distance to the nearest hospital
- Distance to the nearest airport serving more than 250 passengers
- Number of residential parcels in the neighborhood
- Average road density in neighborhood
- Increase in households in neighborhood between 1990 and 2000
- Predicted increase in households in neighborhood between 2003 and 2008
- Standard deviation of elevation in neighborhood

Commercial/Industrial Model Calculation

The commercial/industrial model used the following components. Both commercial and industrial parcels were combined for this analysis. DNRC staff selected the final variables for the commercial/industrial models with GIS technical advice from Geodata Services. Unlike the residential model, which was run with each land office in isolation, the commercial/industrial model was run statewide for all trust land parcels. The longest measured distance required by the analysis was two miles, so the influence of an adjacent land office was not applicable. The model variables included:

1) All parcels within 2 miles of a major town (major towns were defined as those included on the Census 2000 layer from NRIS)
2) Within 1 mile of the 624 largest towns in Montana (from NRIS “Montana towns” GIS layer)
3) Intersection of areas within 1/4 mile of a major highway and within 1/4 mile of an existing commercial or industrial parcel from CAMA commercial property tax database
4) Results of steps 1-3 overlaid with slopes greater and less than 25%, and simulated floodplain to determine developable portions

The resulting grid map was processed with zonal statistics and summarized in the database for each trust land parcel. The deliverable layer for commercial included a selected subset of the trust land map layer that had at least 2 acres of commercial/industrial modeled land within it.

## *Data Attributes for State Trust Land Parcels*

**Table 1 Database attributes for state trust land parcels**

| **Field Name** | **Description** |
|---|---|
| AREA (sq meters) | |
| PERIMETER (meters) | |
| ACRES | |
| TWNRNGSEC | DNRC field |
| EMNT | DNRC field |
| SECTIONACR | DNRC field |
| SURFACEACR | DNRC field |
| SURFLEGAL | DNRC field |
| AREAOFFICE | DNRC field |
| UNITOFFICE | DNRC field |
| COMMENT | DNRC field |
| DATA_PRES | DNRC field |
| ACRE_DIF | DNRC field |
| SOURCE | DNRC field |
| EDIT_DATE | DNRC field |
| FORNONFOR | DNRC field |
| USGSFORNON | DNRC field |
| AUTO_ID | Unique id for each parcel |
| CO_NAME | County name - based on centroid point for parcel |
| **Straight Line Distance Measurements (meters)** | |
| D_res | Residences All – D(Dwelling) or M (Mobile) |
| D_res5 | Residences Built in Last Five Years (2003-1998) |
| D_res10 | Residences Built in Last Ten Years (2003-1993) |
| D_comm | Commercial All |
| D_ind | Industrial All |
| D_bus | Businesses All |
| D_shopctr | Shopping Centers All |
| D_cons | Conservation Easements All |
| D_pstream | Perennial Streams All |
| D_public | Public Land (DNRC parcels excepted) |
| D_roads | Roads All |
| D_Hosp | Hospitals All |
| D_Usgsair | Airports All |
| **DNRC Parcels** | |
| Floodplain | From NHD – perennial streams with ¼ mile buffer. Area in sq meters |
| Floodppct | Percent of parcel in floodplain |
| Slope | From 90 meter DEM – slope greater than 25%. |

| | |
|---|---|
| | Area in sq meters |
| Slopepct | Percent of parcel with slope greater than 25% |
| Develop | Area of parcel outside floodplain and less than 25% slope (“developable”). Area in sq meters. |
| Developpct | Percent of parcel outside floodplain and less than 25% |
| Rdaccess | 1=Road Access / 0=No road access (with 100 meter buffer on roads) for developable portion of DNRC parcels |
| Contiguous | 1=Contiguous / 0=Not Contiguous for DNRC parcels with shared perimeters with combined acreage greater than 660 acres |
| Elev_Stdev | Standard Deviation of elevation (from DEM) |
| Road_Densi | Density of linear features |
| **Values from Thiessen polygons (neighborhoods)** | |
| Av_yrblt | Average year residence built |
| Av_yrrmod | Average year residence remodelled |
| Av_yreff | Average effective year for residence |
| Av_totflv | Average Total Land Value for residence |
| Cnt_res | Count of parcels with a residence in each Thiessen polygon |
| Av_hd_acre | Average housing density/acre based on residence parcel size |
| Av_comland | Average Total Land Value for commercial parcels |
| Cnt_com | Count of commercial parcels in Thiessen polygon |
| Av_indland | Average Total Land Value for industrial parcels |
| Cnt_ind | Count of industrial parcels in Thiessen polygon |
| Dh9000 | Household difference from 1990 to 2000 |
| Dh0308 | Household difference from 2003 to 2008 |
| Dh9000a | Annual rate – household difference 1990 to 2000 |
| Dh0308a | Annual rate – household difference 2003 to 2008 |
| **Quantile Values** (calculated by each land office) | Low=<25%/Medium=25%-75%/High=>75% |
| Q_D_res | 1=Low/2=Medium/3=High |
| Q_D_res5 | 1=Low/2=Medium/3=High |
| Q_D_res10 | 1=Low/2=Medium/3=High |
| Q_D_comm | 1=Low/2=Medium/3=High |
| Q_D_ind | 1=Low/2=Medium/3=High |
| Q_D_cons | 1=Low/2=Medium/3=High |

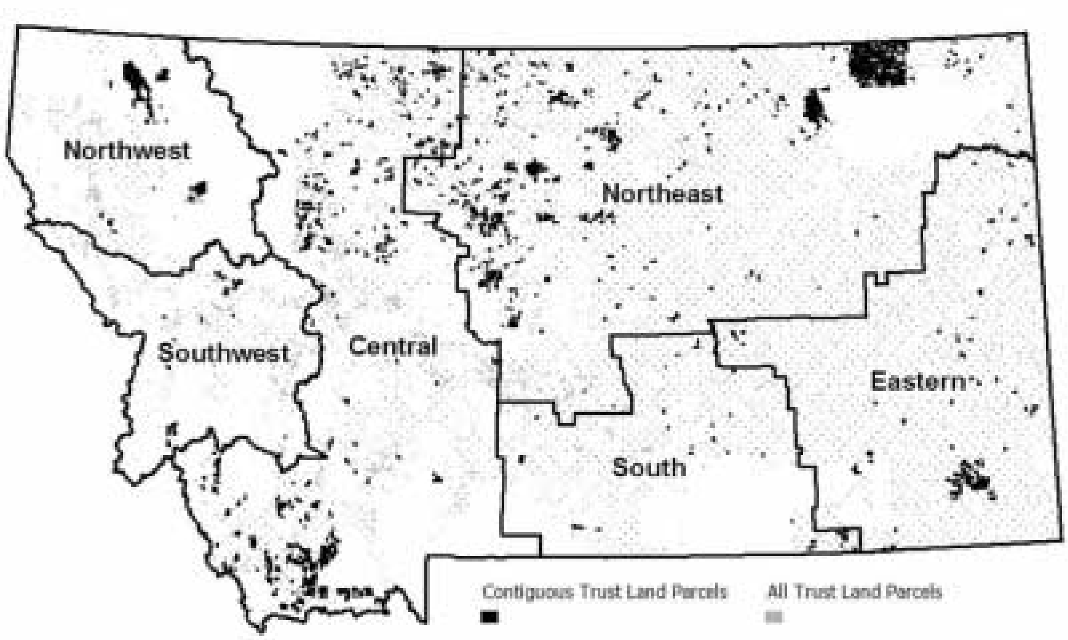
| | |
|---|---|
| Q_D_pstrm | 1=Low/2=Medium/3=High |
| Q_D_public | 1=Low/2=Medium/3=High |
| Q_D_roads | 1=Low/2=Medium/3=High |
| Q_D_bus | 1=Low/2=Medium/3=High |
| Q_D_shop | 1=Low/2=Medium/3=High |
| Q_Av_yrblt | 1=Low/2=Medium/3=High |
| Q_Av_yrrmd | 1=Low/2=Medium/3=High |
| Q_Av_yreff | 1=Low/2=Medium/3=High |
| Q_Av_hdac (Avg Housing Density/Acre) | 1=Low/2=Medium/3=High |
| Q_Av_r_val (Avg Total Land Value for Residence) | 1=Low/2=Medium/3=High |
| Q_Av_c_val (Avg Total Land Value for Commercial) | 1=Low/2=Medium/3=High |
| Q_Av_i_val (Avg Total Land Value for Industrial) | 1=Low/2=Medium/3=High |
| Q_Dh9000 | 1=Low/2=Medium/3=High |
| Q_Dh0308 | 1=Low/2=Medium/3=High |
| Q_Dhosp | 1=Low/2=Medium/3=High |
| Q_D_Usgsai | 1=Low/2=Medium/3=High |
| Q_Elevstd | 1=Low/2=Medium/3=High |
| Q_Rddens | 1=Low/2=Medium/3=High |
| Q_Cnt_res | 1=Low/2=Medium/3=High |
| Q_Fmodel | 1=Low/2=Medium/3=High |
| **Residential Land Model** (calculated by each land office) | |
| Fin_Model | Q_D_res + Q_D_res5 + Q_D_pstrm + Q_D_roads + Q_D_bus + Q_D_shop + Q_D_comm + Q_D_hosp + Q_D_usgsai + Q_cnt_res + Q_rddens + Q_dh9000 + Q_dh0308 + Q_elevstd |

# Methods and analysis procedures

## *State trust land contiguity*

Initial methodology proposed using clusters of trust land parcels, such as the state forests, as the trust land parcel source for neighborhood analyses. Although these clusters of trust land parcels were not used as the unit of analysis in the final methodology, state trust land parcels that were in contiguous blocks were identified for future analysis by dissolving the polygon coverage and determining which resulting parcels were larger than 660 acres (640 acres plus 20 acres to account for section anomalies). Some special uses may be possible in these areas that are not possible elsewhere. Parcels that are contiguous only on one corner, i.e. checkerboard ownership, were not considered contiguous for this step. It also would be useful to examine state trust lands contiguous to public land parcels.  Some idea of contiguity was important, however, particularly in future site analysis following the programmatic GIS.

**Figure 1 Contiguous trust land parcels larger than 1 sq mile**

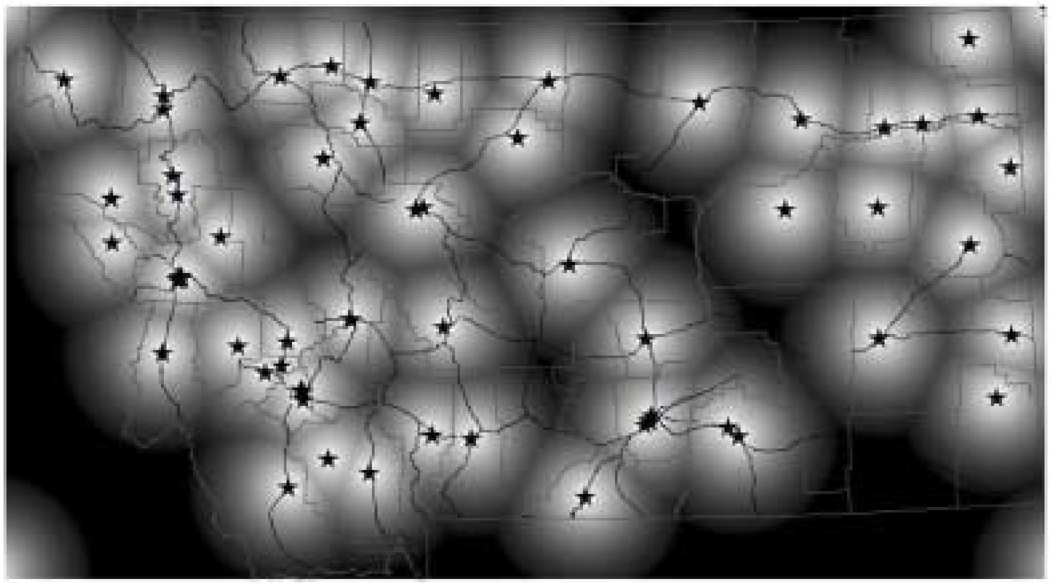



GIS analysis procedures were used to determine which state land parcels were contiguous to other state trust land parcels forming blocks of land larger than 1 square mile in size (See
Figure 1) .  These contiguous parcels were carried in the GIS database but were not used in any acreage calculations or growth potential maps.  All neighborhood analyses used individual trust land parcels ignoring any contiguity between parcels.

## *Distance and acreage measurements for each state trust land parcel*

Initially, a unique identifier was assigned to each state trust land parcel.  The original data set included 12,573 records, some represented multi-part shapes. Multi-part shapes were converted to single part, expanding the number of unique polygons to 13,693.  Detailed GIS steps used in the analysis are included in the Federal Geographic Data Committee (FGDC) compatible metadata for the parcel layer.  Distance to features was measured for multiple attributes.  These measurements involved creating a proximity grid for each source layer and overlaying the DNRC parcel layer to assign the average distance to the selected feature.  All of the distance measurements were Euclidian straight line distance. The figure below shows one examples of these proximity grids.   For simulated floodplains, a component of the development determination, the distance was modified by slope to adjust for a narrower floodplain in steeper areas.

**Figure 2 Euclidian distance to hospitals**



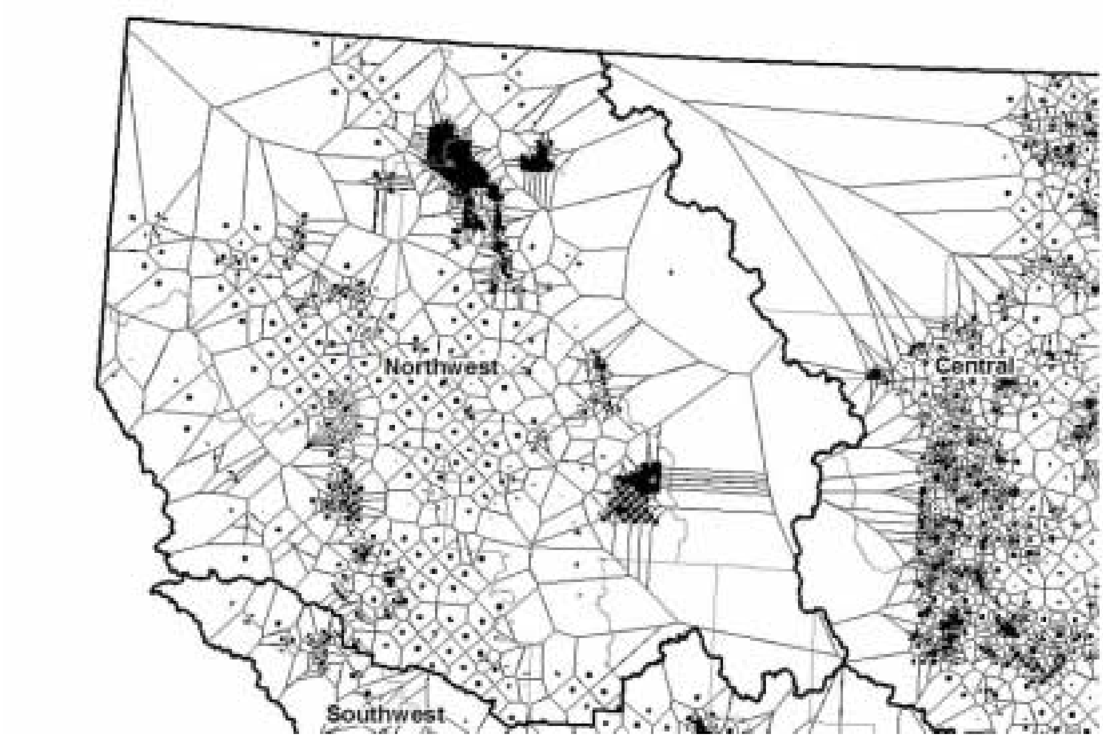
A series of proximity analysis was conducted on multiple data layers from public and commercial sources to contribute to an additive model distinguishing the relative potential for residential and commercial/industrial development for each trust land parcel. These analyses resulted in continuous surfaces to selected features stored as a series of ESRI Grids with 90 meter resolution covering the state of Montana. Zonal statistics were calculated for each distance grid and the resulting mean value posted to the state trust land parcel layer.

## ***Neighborhood analysis for state trust lands***

The neighborhood around each state trust land parcel was defined using Thiessen polygons. Thiessen proximal polygons have the unique property that each polygon contains only one input point, and any location within a polygon is closer to its associated point than to the point of any other polygon.

Analysis involving residences used the CAMA property indicator identifying which parcels had a residence or mobile home. The year the residence was built was also derived from the CAMA database to determine those built in the last five and ten year increments. The CAMA data is oriented around property tax purposes, unlike the census which is focused on population. The CAMA data only recorded the presence or absence of a residence and does not indicate the number of residences on a parcel if more than one existed. Commercial entities like apartments were listed in the commercial CAMA data, but the residential counts used in this study undercounted residences on parcels with multiple occurrences.

**Figure 3 Thiessen polygons defining trust land parcel neighborhoods**




Attributes measuring household differences between 1990 and 2003 and projected differences between 2003-2008 were calculated by extracting ESRI Business Analyst data by census block group with the growth rates assigned to each block group. These were converted to ESRI grid layers with 90 meter resolution cells, each assigned the growth rate for that census block group. The mean value of the growth rate grids were then calculated for each Thiessen polygon from these grids. This provided the basis to calculate an average rate of growth or decline in residential housing in the area around state trust land parcels in the recent past and predicted in the near future.

The cadastral parcels were also used as the unit of analysis for measurements provided to Dr Jackson as the basis for regression models on the economic predictions for residential development. In addition to the variables already described, parcels larger than 1 acre were identified and summarized by county and land office.

**Figure 4 Regression models for economic predictions based on CAMA economic and growth variables**

Subsequently, parcels greater than 1 acre and smaller than 25 acres were identified. The total final land value, total final building value and total cost value of the improvements for each parcel from the CAMA database and total count of parcels with a dwelling and residence from residential parcels were summed by county and land office.

## *Relative potential for residential development in areas near DNRC trust land parcels*

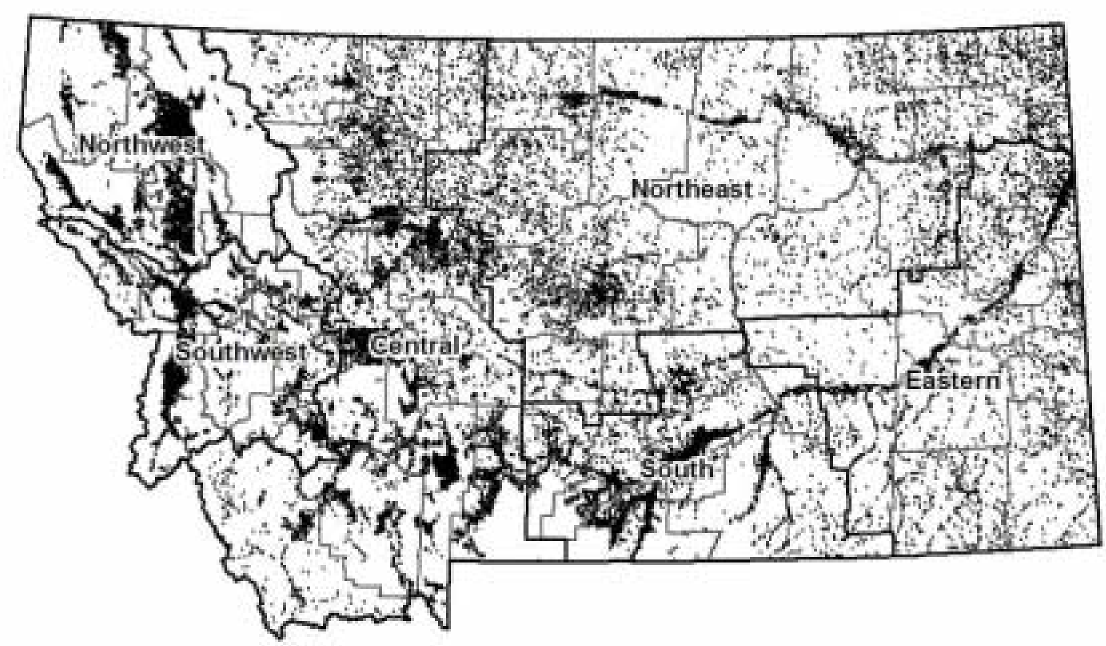
The variables used to summarize the likelihood of residential development were based on previous research and are the variables that are most highly correlated with development in previous studies. Quantile measurements were used to divide each variable into high, medium and low classes. The acreages were then summed for these classes. The simple additive model used to determine the final quantile class values were groupings of these quantile classes. A detailed statistical analysis of the descriptive geostatistical metrics derived in this project was not conducted. Building a suitability index created from a combination of statistical models (logistic regression, regression tree and cluster analysis) could be used to fit an equation to more accurately predict residential development or quantify the relationship of the variables to potential development. This type of analysis could be accomplished using the final data layer we created as part of the more detailed analysis required at the site level. For this analysis, the acreage summaries were tabulated on nominal and ordinal measurement scales, but the underlying data base attached to each state trust land parcel includes continuous variable measurements for future analysis.

The data provided in Table 3 shows the total acres of state trust land with higher potential to be developed in each DNRC land office. The definition of "higher potential" is a relative term. In this instance it is not the result of a statistical model, but is the lands in the highest class of all state trust lands, by each land office, split into four quantiles, grouped into three classes resulting from summing a series of covariate variables commonly agreed to be related to rural residential development. The data do not reflect or infer causation, they were summarized from variables that have been identified in rural residential development research in Montana as highly correlated. In some instances they may be responsible for growth, but in others they could result from the effects of growth. DNRC staff chose to analyze each land office individually, rather than on a statewide basis. For example, features outside of a land office were not measured even if they were closer to a state trust land parcel.

This project examined several studies of rural development and selected common variables from two local studies for this analysis. One was done in the Greater Yellowstone Ecosystem (GYE) (Hernandez, 2004**)**, and the other in the Bitterroot Valley of Western Montana (Christensen, 2002). The primary reason were selected these two studies was the fine scale of geographic granularity of their analysis. The Hernandez study used 1 square mile sections of land and property tax data and the Christensen study used private land parcels and property tax data. Most other analysis of human settlement and growth patterns utilized coarser geographic data as the unit of analysis. These two studies occurred in areas experiencing the fastest growth in Montana and are likely not representative of all areas in the state, particularly the rural agricultural portions of the eastern and central portion. These two studies do reflect the high growth portions of the state which are ranked relatively more likely to experience future rural residential development.

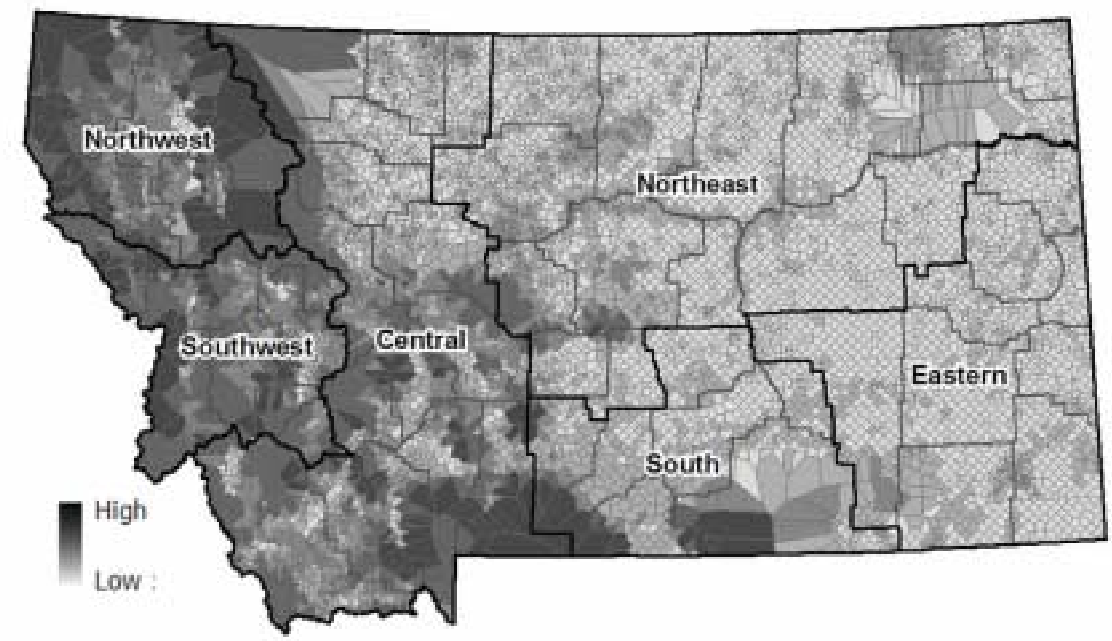
The sign or direction of the correlation was generally similar between the two studies for almost all variables. Only a few attributes had conflicting results. Those that were in conflict regarding the direction (positive or negative) of the relationship were not included in the summary results.

Figure 5 Housing density - each dot represents a parcel with a residence




Among the strongest correlation in both studies was existing density of development and encroachment, showing a positive correlation to future rural residential development. Variance in elevation was a significant variable in the Hernandez study, and in the Christensen study, they measured "viewshed" characteristics, including number of peaks in sight from each parcel. Transportation variables were strongly correlated in both studies, with road density a positive relationship, and a negative relationship for travel distance to town and distance to a state or county road. In the service class of variables in the Hernandez study driving distance to airports and hospitals were the most highly correlated negative relationship, and similar patterns were found in the Bitterroot with distance to schools, service businesses and all businesses .

Figure 6 Elevation variance positively correlated with residential growth




Distance to major steams, rivers and water bodies was negatively correlated with growth in both studies, there was less development farther away from perennial and intermittent water sources.

**Figure 7 Services including airports and hospitals were important predictors of residential growth**

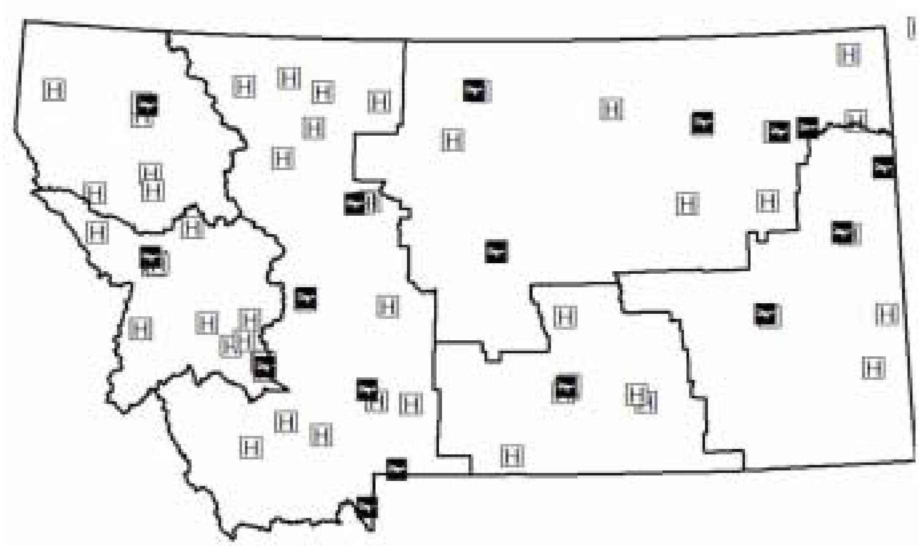


**Figure 8 Household growth rates by census block group 1990-2000**

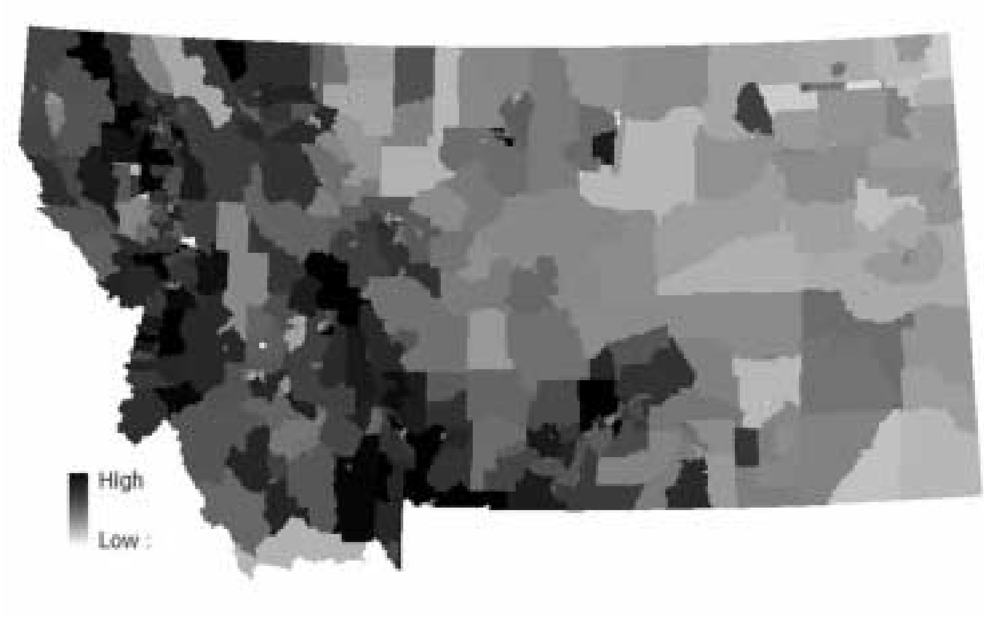



**Figure 9 Road density per square mile**

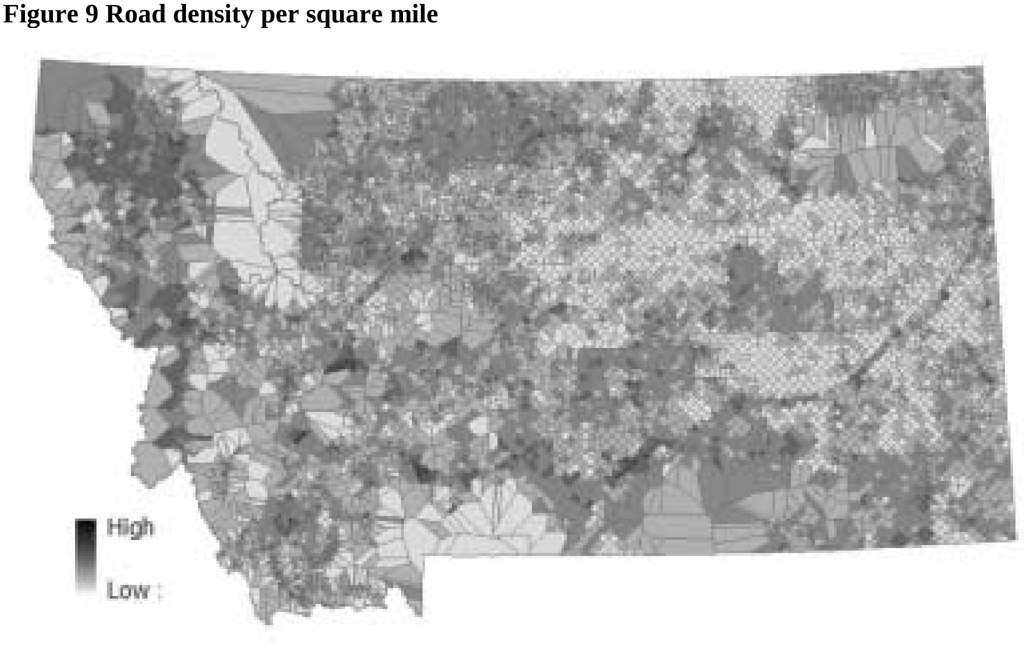
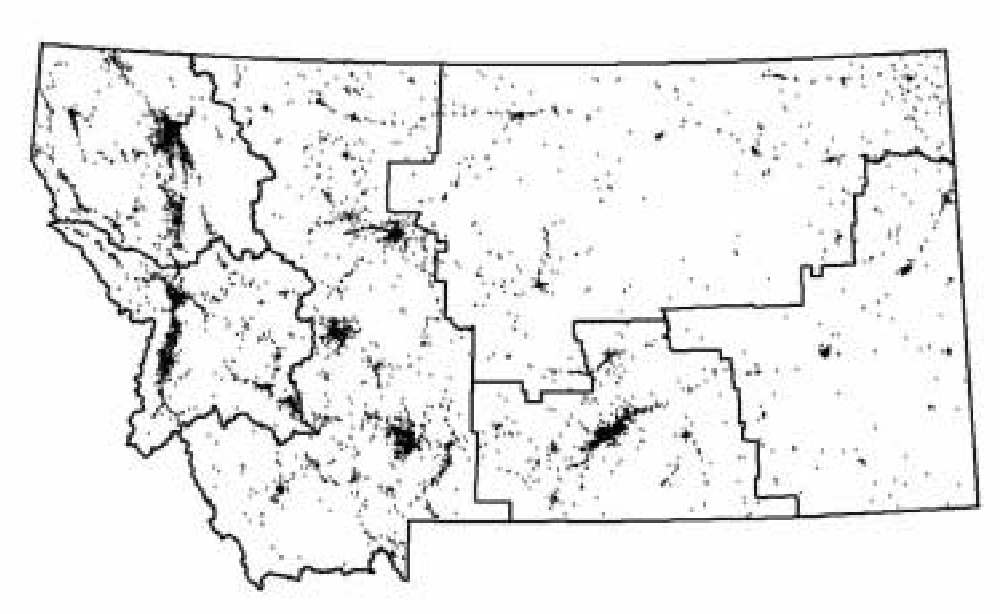


**Figure 10 Commercial activity - each point is a Montana business**



There were mixed results in the correlation of public lands and conservation easements to growth and development. In the Hernandez study near the GYE there was a strong negative relationship between rural residential growth and distance to National Parks (development decreased as distance from National Parks increased), but the relationship was positive for all public lands and conservation easements (area near towns that were further from public lands and easements tended to experience more growth). The Christensen study showed negative relationships for proximity to all categories of public lands and easements. The Hernandez study provides a possible explanation for their results attributing it to the vast difference in types of public lands. Due to these discrepancies, the proximity measures calculated for trust land parcels in the summed model for trust lands were not used. The Hernandez study examined a few variables that were not measured in the Christensen study, such as educational attainment and agricultural productivity that were strongly related to growth in the GYE area. These were not measured in the examination of state trust land parcels.

Using the two site specific Montana studies, the measurable attributes which best fit the residential growth models were selected. Acreages were calculated for the attributes, listed in Table 2 in italics, individually for the immediate neighborhood around each state trust parcel (defined by Thiessen polygons), or the distance measurement directly to the state trust land parcel, either based on metrics of total counts, average density, or proximity distance measurements, and classified each into three quantiles, by land office. High, medium, and low class values were assigned: High=>75%, Medium=25-75%, Low=<25%. Those variables that were negatively correlated were inverted to standardize the subsequent comparison in an additive model. As a result all variables were assigned a standardized quantile ranking based on the indication of likelihood of development.

**Table 2 Attributes Included in the Model – All Were Classed into Quantiles**

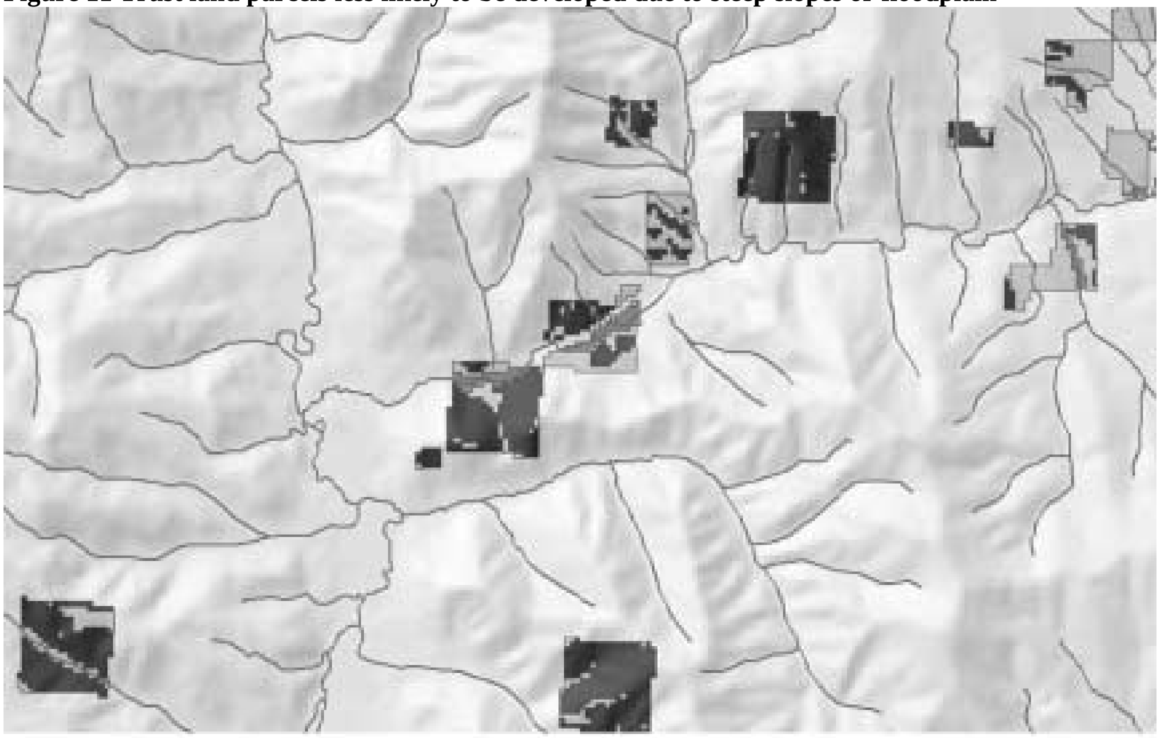
| | |
|---|---|
| -Q_D_RES | Distance to nearest residence |
| -Q_D_RES5 | Distance to nearest residence in neighborhood built in the last 5 years |
| -Q_D_PSTRM | Distance to nearest perennial stream |
| -Q_D_ROADS | Distance to nearest state or county road |
| -Q_D_BUS | Distance to nearest commercial business (by address) |
| -Q_D_SHOP | Distance to nearest major shopping center |
| -Q_D_COMM | Distance to nearest commercial parcel |
| -Q_D_HOSPITAL | Distance to nearest hospital |
| -Q_D_USGSAI | Distance to nearest airport serving more than 250 passengers |
| +*Q_CNT_RES* | Number of residential parcels in neighborhood |
| +*Q_ROAD_DEN* | Average road density in neighborhood |
| +*Q_DH9000* | Increase in households in neighborhood between 1990-2000 census |
| +*Q_DH0308* | Predicted increase in households in neighborhood between 2003-2008 (ESRIBis estimate) |
| +*Q_ELEVSTD* | Standard deviation of elevation in neighborhood |

These rankings were then summed across all ordinal scaled variables and the results were again classified into four quantiles, and assigned into three classes using the same percentage classes (High=>75%, Medium=50-75%, Low=<25%) . The upper quantile of the composite highly likely parcels was then cross referenced against the acres potentially developable within that parcel and the resulting acres summed by land office to create the results in Table 3 and depicted in Figure 14.

## *Developable portions of DNRC parcels*

In addition to the potential for residential development, the approximate acreage of trust land parcels likely to be developable was also calculated, subtracting out portions of parcels with physical constraints and classifying them as unlikely to be developed for residential purposes. As a practical rule of thumb, a slope limit and simulated floodplain was used to define these areas. The slope grid was reclassified into slopes more than and less than 25%, the cutoff for septic system regulations in Montana.

**Figure 11 Trust land parcels less likely to be developed due to steep slopes or floodplain**

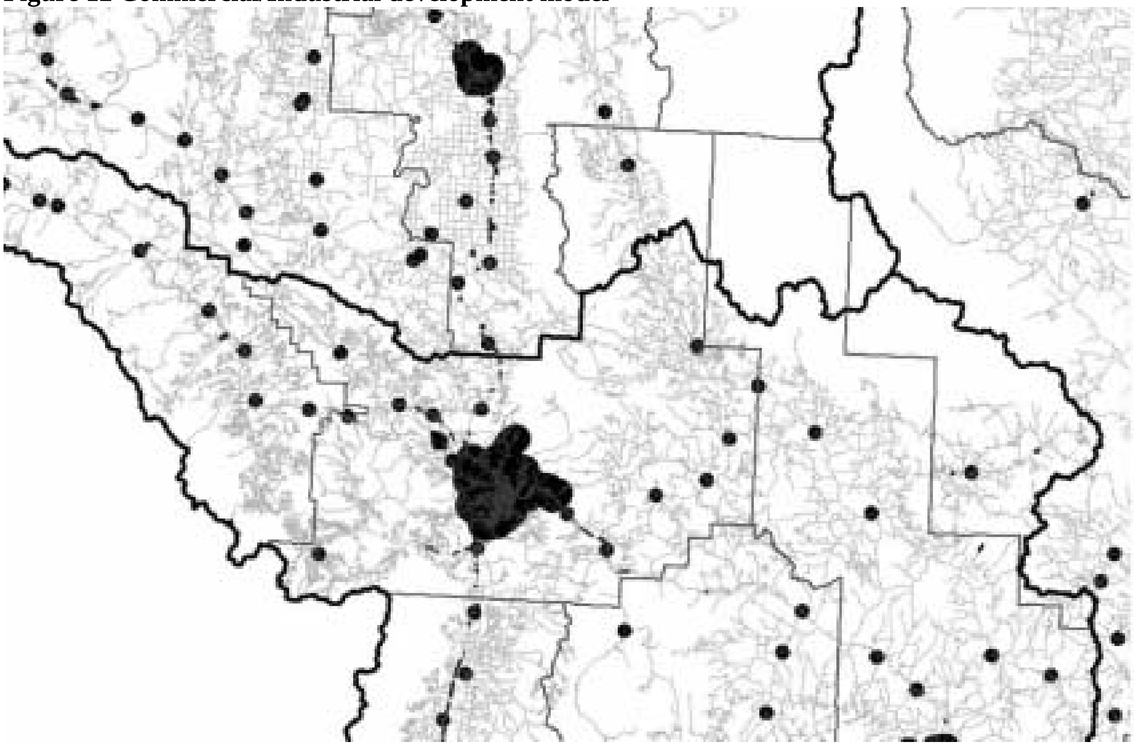


As described in the data section, floodplain was simulated using the perennial streams identified in the National Hydrologic data set mapped at a scale of 1 to 100,000. Buffers of ¼ mile were derived around these streams and modified with an inverse relationship by the slope grid, making the simulated floodplain buffer narrower where slopes were steeper. The union of these two analysis grids was then intersected with the DNRC parcels converted to a grid with the same cell size. The resulting grid, splitting the trust land parcels into two classes, developable and non-developable was then used to calculate acreages in each land office.

## *Relative potential for commercial and industrial development*

No studies similar to the residential model research in the previous section were located for commercial and industrial development potential.

**Figure 12 Commercial/Industrial development model**

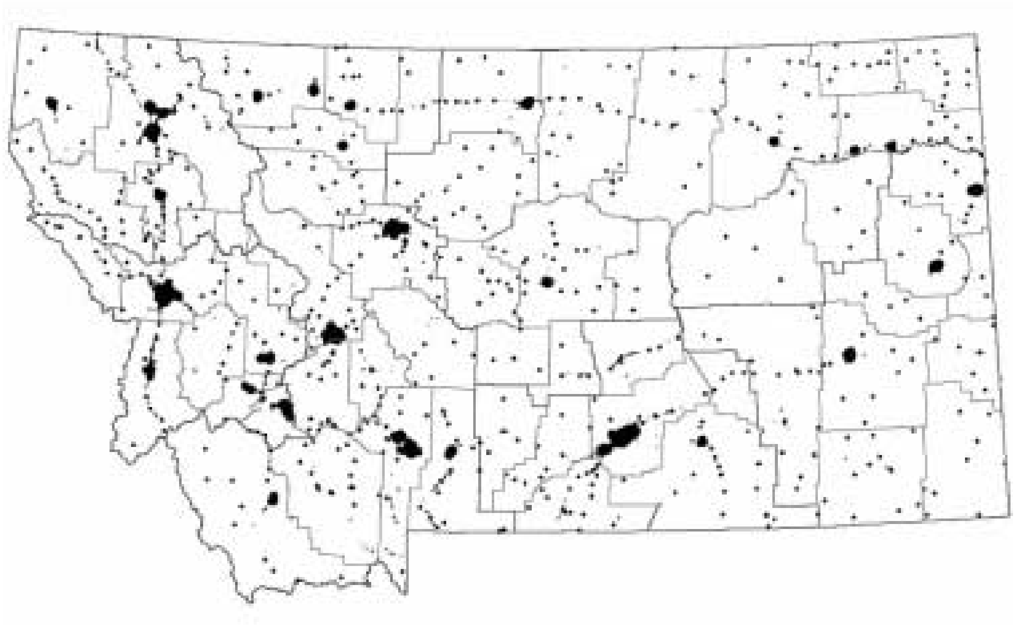


The model included the following components:

1) The Census 2000 layer from NRIS is a polygon layer of major cities in Montana derived from data from the Census Bureau. Some cities also have digital city boundaries and urban area maps, but variability in availability and standards for creation of the digital data precluded use of more detailed local data. A Euclidian distance grid was created based on the distance from the external boundary of the major city polygon layer. This was subsequently resampled to two classes, those within or outside a 2 mile buffer of a major town.
2) An identical analysis was run on areas within and outside a 1 mile buffer of the 624 largest towns in Montana (from NRIS "Montana towns" GIS layer).
3) Separate proximity distance grids were created for the areas within 1/4 mile of a major highway and within 1/4 mile of an existing commercial or industrial parcel from property tax database
4) The resulting four grids were summed, and all intersecting areas were kept in the model. The results were overlaid with developable lands, slopes greater and less than 25% and outside of simulated floodplain (the same map layer as the residential model was used) to determine developable portions of commercial and industrial parcels. The resulting statewide grid was overlaid on the land offices and the acreages of commercial/industrial lands were calculated for each land office. We also overlaid the results with all trust parcels and selected the subset of trust parcels that included at least 2 acres of commercial or industrial land in the model.

When the analysis was complete, final commercial/industrial grid was overlaid with the developable residential land to derive an overlap map. The acreage totals of this analysis were subtotalled by land office.

**Figure 13 Commercial model - all areas in Montana**



## *DNRC land office summarization*

The analysis described in the previous sections was conducted on finer grained scaled data layers. The final step in the analysis was to summarize the data to the DNRC land office level suitable for the analysis in the programmatic GIS. The source data will have utility beyond the current analysis for subsequent site analysis in areas smaller than the land office administrative boundaries.

The parcel data was tabulated for each land office and summarized.

- Categorize values for each variable into three standard deviations and assign class values
- Summarize acreage of state trust land more and less likely to be developed for residential uses
- Summarize acreage of state trust lands more likely to be developed for commercial and industrial uses
- Acreage summarization within DNRC land office regions
- Prepare spreadsheet of data metrics for each state trust land parcel

## Analysis Results

The results of the GIS analysis are included below. Figure 14 through Figure 16 State trust land parcels in lower quantile of residential development show the geographic distribution of each of the quantile categories.

**Table 3 All Developable acres by land office**

| AREA OFFICE | QUANTILE | COUNT | TOTAL ACRES | DEVELOPABLE ACRES |
|---|---|---|---|---|
| CLO | 3 | 680 | 228,261 | 167,773 |
| CLO | 2 | 2,059 | 629,700 | 506,089 |
| CLO | 1 | 1,242 | 403,704 | 327,880 |
| **CLO Subtotal** | | **3,981** | **1,261,665** | **1,001,742** |
| | | | | |
| ELO | 3 | 326 | 128,015 | 114,261 |
| ELO | 2 | 1,154 | 577,769 | 534,260 |
| ELO | 1 | 518 | 274,029 | 261,357 |
| **ELO Subtotal** | | **1,998** | **979,813** | **909,878** |
| | | | | |
| NELO | 3 | 997 | 317,478 | 284,097 |
| NELO | 2 | 2,877 | 1,079,331 | 995,784 |
| NELO | 1 | 1,601 | 617,661 | 573,225 |
| **NELO Subtotal** | | **5,475** | **2,014,470** | **1,853,106** |
| | | | | |
| NWLO | 3 | 139 | 42,158 | 28,268 |
| NWLO | 2 | 387 | 162,670 | 82,074 |
| NWLO | 1 | 256 | 111,357 | 42,516 |
| **NWLO Subtotal** | | **782** | **316,184** | **152,858** |
| | | | | |
| SLO | 3 | 157 | 62,799 | 53,959 |
| SLO | 2 | 435 | 218,197 | 195,160 |
| SLO | 1 | 253 | 111,969 | 105,726 |
| **SLO Subtotal** | | **845** | **392,965** | **354,845** |
| | | | | |
| SWLO | 3 | 121 | 37,199 | 19,027 |
| SWLO | 2 | 321 | 124,046 | 72,017 |
| SWLO | 1 | 170 | 75,259 | 51,333 |
| **SWLO Subtotal** | | **612** | **236,504** | **142,377** |
| | | | | |
| **TOTAL** | | **13,693** | **5,201,601** | **4,414,806** |

**Figure 14 State trust land parcels in upper quantile of residential development**

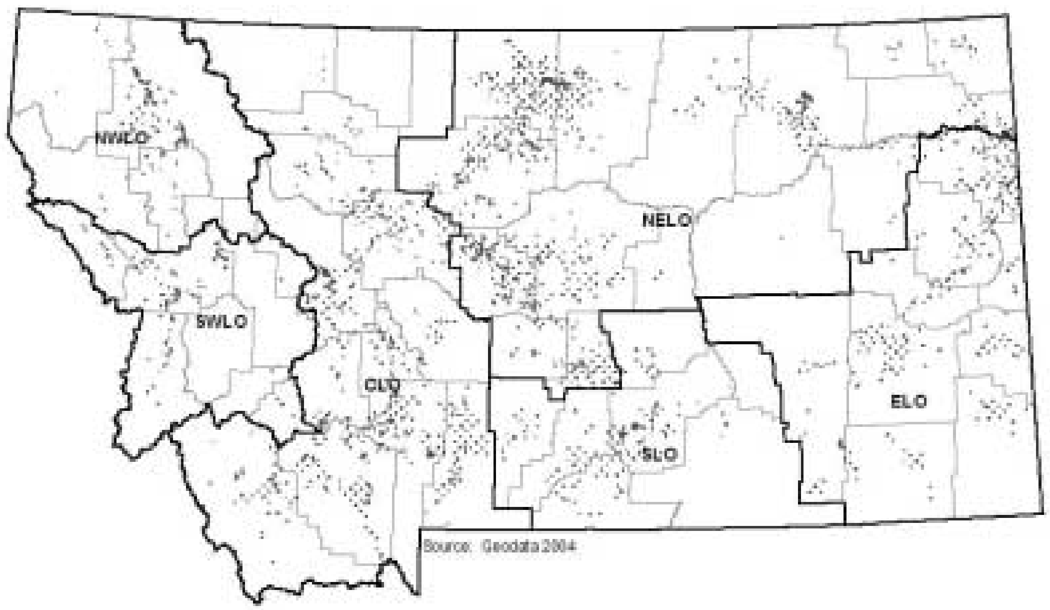



**Figure 15 State trust land parcels in middle quantile of residential development**

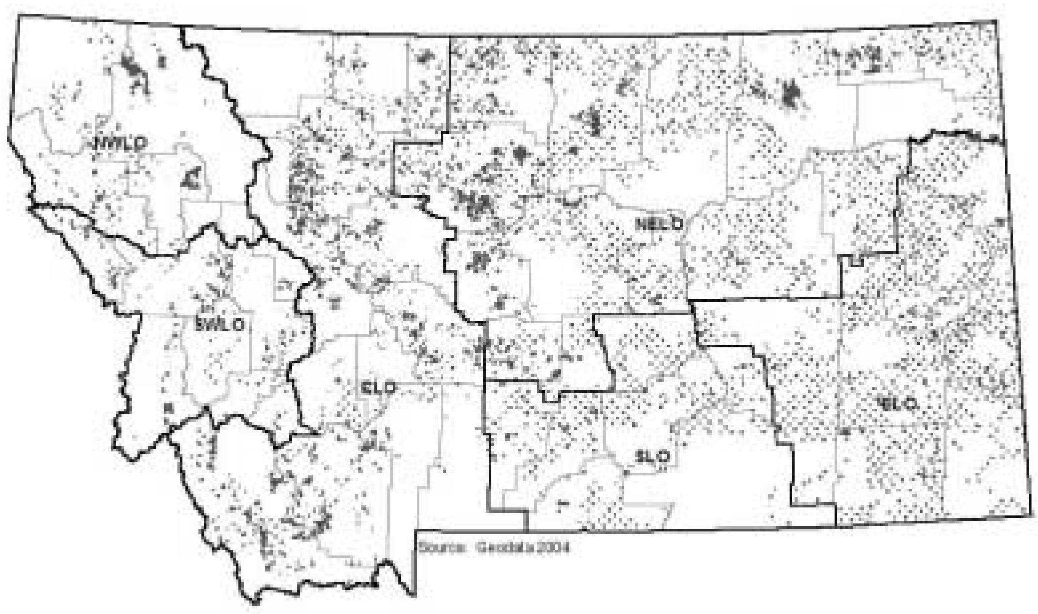


**Figure 16 State trust land parcels in lower quantile of residential development**

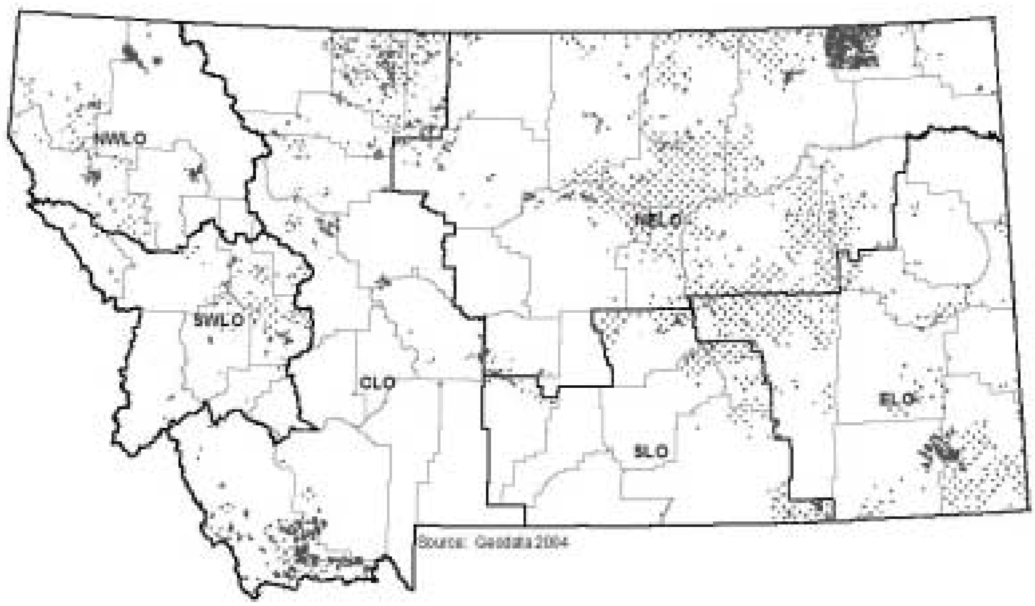



Table 4 shows all commercial/industrial potential land acreages by land office in two categories (developable and non-developable). Table 5 shows the portion of the commercial/industrial potential land acreages that fall within DNRC developable parcels, also by land office.

**Table 4 Acreage of all commercial and industrial parcels developable and not developable**

| All Commercial & Industrial | Acres |
|---|---|
| SWLO Develop | 307,622 |
| SWLO Non develop | 69,292 |
| SLO Develop | 292,668 |
| SLO Non Develop | 8,526 |
| NWLO Develop | 270,582 |
| NWLO Non Develop | 29,572 |
| ELO Develop | 244,220 |
| ELO Non Develop | 1,424 |
| CLO Develop | 663,688 |
| CLO Non Develop | 45,370 |
| NELO Develop | 395,630 |
| NELO Non-Develop | 4,572 |

**Table 5 Developable acreage of commercial and industrial trust land parcels**

| DNRC Developable Commercial & Industrial | Acres |
|---|---|
| SWLO Develop | 6,052 |
| SLO Develop | 9,104 |
| NWLO Develop | 6,940 |
| ELO Develop | 9,336 |
| CLO Develop | 16,330 |
| NELO Develop | 17,220 |

## References

Hernandez, P.A,  and advisors Hansen, A.J., Rasker, R., Maxwell, B (2004) “Rates and Drivers of Rural Residential Development in the Greater Yellowstone”,  Masters Thesis, Montana State University

Christensen, N. A., Landres, P. B. (2002).  “Modeling residential development behavior in the urban/forest interface with the Bitterroot National Forest in Montana.”  Book of Abstracts, 9th International Symposium on Society and Resource Management: Choices and Consequences – Natural Resources and Societal Decision-Making,  June 2 –5, Indiana University, Bloomington.